PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H05B 37/02, 41/36

A1

(11) International Publication Number: WO 93/23974

(43) International Publication Date: 25 November 1993 (25.11.93)

(21) International Application Number: PCT/US93/04468

(22) International Filing Date: 17 May 1993 (17.05.93)

(30) Priority data:
886,718 20 May 1992 (20.05.92) US

(71) Applicant: DIABLO RESEARCH CORPORATION [US/US]; 130 Kifer Court, Sunnyvale, CA 94086 (US).

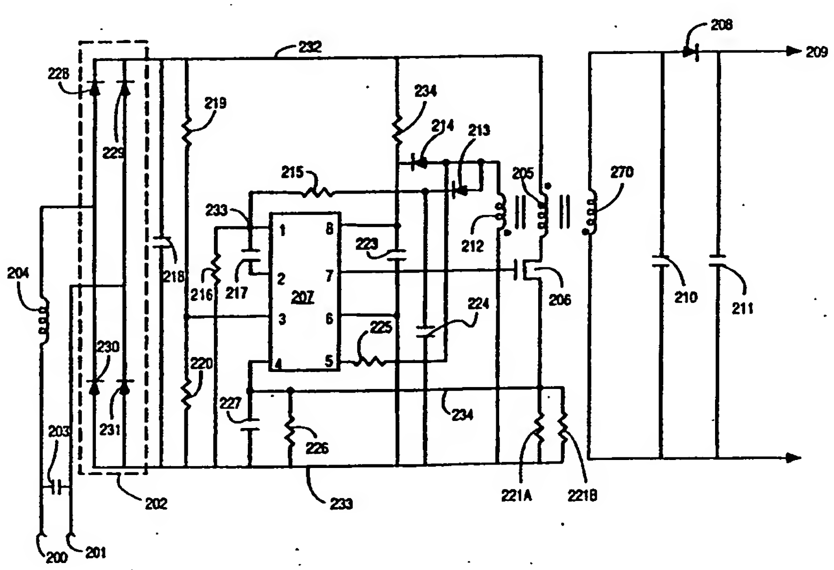
(72) Inventors: SIAO, Roger ; 500 West Middlefield Road, #111, Mountain View, CA 94043 (US). VRIONIS, Nickolas, G. ; 22181 Alderney Court, Los Altos, CA 94022 (US).

(74) Agents: STEUBER, David, E. et al.; Skjerven, Morrill, MacPherson, Franking & Friel, 25 Metro Drive, Suite 700, San Jose, CA 95110 (US).

(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
With amended claims.

(54) Title: STABLE POWER SUPPLY WITH HIGH POWER FACTOR



(57) Abstract

A power supply having a high power factor and low harmonic distortion which is stable in either an electrically isolated system or an electrically non-isolated system is provided. In the power supply for the electrically isolated system, a controller (207) is coupled to an AC voltage source and a primary winding (205). The primary winding (205) is inductively coupled to a secondary (270) and an auxiliary winding (212). The secondary winding (270) provides the output DC voltage. The secondary winding (270) and auxiliary winding (212) are formed in a tight magnetic coupling. The auxiliary winding (212) provides a voltage supply for the controller (207) and also provides an accurate representation of the output voltage to the controller (207) in a voltage feedback path. The separate voltage feedback path to the controller isolates the distortion which is inherent in the voltage supplied to the controller (207).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	MR	Mauritania
AU	Australia	GA	Gabon	MW	Malawi
BB	Barbados	GB	United Kingdom	NL	Netherlands
BE	Belgium	GN	Guinea	NO	Norway
BF	Burkina Faso	GR	Greece	NZ	New Zealand
BG	Bulgaria	HU	Hungary	PL	Poland
BJ	Benin	IE	Ireland	PT	Portugal
BR	Brazil	IT	Italy	RO	Romania
CA	Canada	JP	Japan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SK	Slovak Republic
CI	Côte d'Ivoire	KZ	Kazakhstan	SN	Senegal
CM	Cameroon	LI	Liechtenstein	SU	Soviet Union
CS	Czechoslovakia	LK	Sri Lanka	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	MC	Monaco	UA	Ukraine
DK	Denmark	MG	Madagascar	US	United States of America
ES	Spain	ML	Mali	VN	Viet Nam
FI	Finland	MN	Mongolia		

"STABLE POWER SUPPLY WITH HIGH POWER FACTOR"

Cross-Reference to Related Applications

This application is related to, and incorporates by reference, the following U.S. patent application filed on the same date as the present application: the application entitled "Class D Amplifiers" filed by Roger Siao, Serial No. 07/887168 filed May 20, 1992.

BACKGROUND OF THE INVENTION

This invention relates to power supplies providing a high power factor and low harmonic distortion, and in particular to a power supply for an electrodeless discharge lamp in either an electrically isolated system or in an electrically non-isolated system.

Description of Related Art

Power supplies which convert an AC voltage to a DC voltage while providing a high power factor and low harmonic distortion are well known in the art. The power factor, defined as the ratio of actual input watts to the total root-mean-square (RMS) volt-amperes input, varies between zero and one. The better the power supply, the closer the power factor is to one. Harmonic distortion refers to the input current distortion of the power supply which is characterized by the magnitude of the sum of individual current harmonics relative to the fundamental component when the input voltage signal is sinusoidal. Total harmonic distortion of the input current to the power supply affects the efficiency of the power system in providing a high power factor. The purpose of the above-referenced power supply is to receive an input AC voltage

and produce one or more regulated DC voltages at its output for powering components in a system.

One example of a power supply comprises a controller for providing a high power factor, means for powering this controller internally, and associated circuitry for ensuring a low current harmonic distortion to the power line. However, power supplies for discharge lamps, and in particular for supplying power to electrodeless discharge lamps, currently fail to provide a high power factor with low total harmonic distortion.

Moreover, the power supply can further comprise a transformer to electrically isolate the power supply from other parts of the system, thereby reducing the risk of electrical shock to the end user. This electrical isolation creates significant problems associated with the stability of the controller. Specifically, the controller requires an accurate sensing of the output voltage to remain stable, i.e. perform optimally. This sensing as performed by prior art power supplies which provide isolation is inaccurate. Thus, a stable power supply is needed which provides a high power factor and low total harmonic distortion to the power lines in an electrically isolated system (for example, in an electrodeless discharge lamp).

SUMMARY OF THE INVENTION

In accordance with the present invention, a stable power supply with a high power factor and low harmonic distortion is provided for use in an electrically isolated system. In this power supply, a controller is coupled to an AC voltage source and is further coupled to a primary winding. The primary winding is inductively coupled to a secondary winding which induces output current, thereby providing an appropriate output DC voltage for the system. The primary winding is further inductively coupled to an auxiliary winding. Moreover, the secondary winding and

the auxiliary winding are formed in a tight magnetic coupling. The voltage across the auxiliary winding is rectified and filtered to provide a DC voltage supply to power the controllers.

Stability of the controller is ensured by providing a separate voltage feedback path from the auxiliary winding to another input pin of the controller which provides the controller with an extremely accurate representation of the output voltage. The voltage feedback path includes a diode for rectifying, a capacitor for filtering, and a resistor. Providing a separate voltage feedback path to the controller isolates the voltage distortion which is inherent in the voltage supplied to the voltage supply pin of the controller. Moreover, because of tight magnetic coupling between the secondary and auxiliary winding, the sensing accuracy of the output voltage by the controller is dramatically increased. In this manner, the operation of the power supply is optimized. In one embodiment, the power system described above is used for an electrodeless discharge lamp. In another embodiment, the power system is used to power any discharge lamp which employs a metal vapor and a rare gas, or a fluorescent electroded compact lamp.

In further accordance with the present invention, a power supply with a high power factor and low harmonic distortion is provided for use in an electrically non-isolated system. Using this power supply dramatically increases energy savings to the utility supplying the power and also ensures greater safety conditions for both the utility and the end user. This power supply may be used in an electrodeless discharge lamp, a discharge lamp which employs a metal vapor and a rare gas, or a fluorescent electroded compact lamp.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates one embodiment of the present invention which provides a stable power supply having a high power factor and minimal harmonic currents to the power lines in an electrically isolated system.

Figure 2 illustrates a schematic of a power supply using a stepped-up converter in an electrically non-isolated system.

Figure 3 illustrates a schematic of a power supply using a stepped-down converter in an electrically non-isolated system.

DETAILED DESCRIPTION OF THE DRAWINGS

One example of a power system providing a high power factor and minimizing harmonics is disclosed in a product preview, hereby incorporated by reference in its entirety, of a Power Factor Controller (MC 34261 or MC33261) manufactured by Motorola and currently available in the market. For convenience, a listing is provided in Table 1 of the various pin connections to the controller and their functions. The internal operation of controller, which is well known to those skilled in the art, is not described in detail. Note other controllers having similar pin functions may also be used in accordance with the present invention.

Table 1

Pin Number	Pin Connection Function
1	Voltage Feedback Input
2	Compensation
3	Multiplier Input
4	Current Sense Input
5	Zero Current Detect Input
6	Ground
7	Drive Output
8	Vcc

Figure 1 illustrates one embodiment of the present invention which provides stability in an electrically

isolated power supply system. Referring to Figure 1, an AC voltage of 95 - 132 volts at 60 Hz is applied to lines 200 and 201. Inductor 204, in combination with capacitor 203, acts as a low pass filter for signals on lines 200 and 201. In addition, inductor 204, combined with capacitors 203 and 218, forms a bilateral low pass filter which efficiently filters out transient signals in the power lines from interfering with or damaging the circuitry illustrated in Figure 1.

This input AC voltage is transformed into a raw DC voltage by a diode bridge 202 which includes diodes 228-231. The diodes used in this embodiment are general purpose diodes, for example of the type 1N4003. Capacitor 218, connected in parallel with diode bridge 202 and typically having 0.22 farads, provides a low AC impedance between line 232 and line 233 (ground). A voltage divider comprising resistors 219 and 220, having resistances of 560K and 10K, respectively, attenuates this rectified voltage down to a very low level of, for example, between zero and 3.5 volts. This attenuated signal is then transferred to pin 3 of controller 207. Controller 207 senses the voltage on pin 3 and multiplies this voltage by the current through an N-channel MOSFET transistor 206 (sensed by current sense input pin 4).

The raw DC voltage, provided by diode bridge 202 on line 232, is transferred to primary winding 205 which is coupled to a drain of the N-channel MOSFET 206. The DC voltage on line 232 is referred to as raw voltage because it is unregulated and unsuitable for the power supply user.

However, in contrast to prior art power supply systems described generally above, the system illustrated in Figure 1 provides electrical isolation between the power supply user (for example an amplifier) and the power line by making use of a secondary winding 270. Note that when transistor 206 is on, energy is stored in primary

winding 205 because of the current directions established in secondary winding 270 and auxiliary winding 212 (these directions are indicated as dots in Figure 1). The energy stored in primary winding 205 is transferred during the off times of transistor 206 to secondary winding 270 and auxiliary winding 212 placed in operative relation to primary winding 205 (due to the reverse polarities of the voltages established across secondary winding 270 and auxiliary winding 212).

Because of the tight magnetic coupling between secondary winding 270 and auxiliary winding 212, the voltage across auxiliary winding 212 is proportional to the voltage across secondary winding 270. This proportionality is a function of the number of turns in each winding. In one embodiment of the present invention, primary winding 205 and secondary winding 270 each have 71 turns, whereas auxiliary winding 212 has 8 turns, thereby effectively scaling down the voltage provided by auxiliary winding 212. The voltage across secondary winding 270 is then rectified via diode 208 and is then converted to a usable DC voltage on line 209.

The voltage appearing across auxiliary winding 212 is rectified by diode 214, is capacitively filtered by capacitor 223 (typically providing 22 microfarads), and is then applied to the supply voltage Vcc pin 8. Therefore, controller 207 consumes the magnetic energy which is provided by the auxiliary winding 212. Resistor 225, having a resistance of about 22K, is used to sense the zero current condition of primary winding 205 by making use of the induced current through auxiliary winding 212.

Two resistors 221A and 221B, connected in series to the source of transistor 206 and each having a resistance of 2.7 Ohms, detect the peak current through primary winding 205 which is applied to pin 4 of controller 207. If controller 207 senses a voltage on pin 4 which exceeds typically 1.2 volts, controller 207 will lower the voltage

on pin 7 to turn off transistor 206. Capacitor 227 which is connected to line 233 (which is circuit ground) and line 234, serves to filter out high frequency noise generated when turning transistor 206 on or off. Resistor 226, which is connected in parallel with resistors 221A and 221B, serves as a backup in the event that resistors 221A and 221B are burned out due to high inductive current. In other words, resistor 226 serves as a safety factor in case the circuit goes into an abnormal operating mode. Note that resistor 226 has a much larger resistance (47 Ohms) than either resistor 221A or 221B. As a result, resistor 226 consumes much less power as compared to resistors 221A and 221B.

Capacitor 217, typically providing 0.22 microfarads, is coupled between the frequency compensation pin 2 of controller 207 and voltage feedback input pin 1 of controller 207. Capacitor 217 provides a roll-off pole for an active filter (not shown) in controller 207.

In accordance with the present invention, circuitry is provided which stabilizes a controller system that is electrically isolated from the output DC voltage. As noted previously, controller 207 senses the voltage level across auxiliary winding 212 on pin 1 (which represents the output voltage across secondary winding 270) and determines whether the output voltage is too low or too high. In addition to diode 214, diode 213 also rectifies the induced voltage through auxiliary winding 212. Capacitor 224, coupled to the output of diode 213 and providing about 0.1 microfarads, serves as an AC filtering element for the voltage feedback to pin 1. Moreover, resistors 215 and 216 are serially connected to diode 213 and form a voltage divider network coupled to voltage feedback input pin 1. Note resistor 216 is also connected to ground.

In this manner, the voltage which is sensed by controller 207 on pin 1 is not distorted by current drawn

from the controller itself via, for example, pin 8. Specifically, the voltage supplied to pin 8 via diode 214 fluctuates due to the heavy load on capacitor 223 by controller 207 (i.e. controller 207 draws substantial current from capacitor 223). Note resistor 234, having a resistance of 100K and coupled between line 232 and pin 8, provides the initial energy to power up controller 207. In contrast, there is minimal loading on capacitor 224 due to the high impedance of resistors 215 and 216 (i.e., controller 207 draws insignificant current through pin 1). Thus, the output voltage on line 209 is accurately (indirectly) reflected on pin 1, thereby ensuring stable operation and better output voltage regulation of controller 207. In the embodiment described above, a stable power supply system is provided which achieves a power factor of 95% or better and a total harmonic current distortion of approximately 3½%.

In another embodiment of the present invention shown in Figure 2, a power factor controller, described previously as either MC 34261 or MC33261, is used as a power-up converter in an electrically non-isolated system for an electrode discharge lamp. Heretofore, power systems for electrode discharge lamps failed to provide a high power factor with low total harmonic distortion. Note that devices having functions similar to or identical to the devices described in detail for Figure 1 are referenced by the same numerals. The values for these devices are disclosed in the Motorola product preview previously mentioned.

In a case where the power factor is less than one (1), the utility supplying the power must size its transformers and supply lines in accordance with the higher volt-amperes associated with the power supply. A power factor of typically 0.5 and 150% total harmonic distortion doubles the actual power capacity requirements of the utility. Therefore, increasing the power factor to

approach one is an important factor in improving energy savings for the utility.

Moreover, reduction of total harmonic distortion is an important safety factor for both the building in use and the supply transformers of the utility. If a high total harmonic distortion is present in a building having a three wire system and neutral leg (a typical wiring configuration), a serious fire hazard can occur in the following manner. Note that circuits for lighting are usually dedicated and thus lighting comprises the total load. As is well known in the art, the sum of the odd triplets (3, 9, 15, 21 etc.) harmonics frequencies add, thereby increasing the current in the neutral leg which can exceed its rating and start a fire. Also when high total harmonic distortion exists, transformer heating for a given current is increased, again creating a safety issue or a cost penalty by increasing the transformer size to compensate for the increased heating.

Therefore, a power supply providing a high power factor and low total harmonic distortion ensures dramatic increases in energy savings and safety conditions for any lamp. Specifically, the advantages associated with the electrodeless discharge lamp, i.e., energy savings and long life, are fully achieved only with the use of the power system having a high power factor and low total harmonic distortion.

In another embodiment of the present invention shown in Figure 3, the power factor controller described above for Figure 2 is used as a power-down converter in an electrically non-isolated system for an electrodeless discharge lamp. Identical or similar devices described in detail for Figure 1 are referenced by the same numerals. The values for those devices are described in detail in reference to Figure 1. Note the series network of resistor 252 and capacitor 253 forms a snuffer to damp out high frequency ringings caused by the leakage inductance

of primary winding 205. Further note that resistor 252 typically has a resistance of 3.9K ohms and the capacitor 253 provides 47 picofarads.

The description of the present invention detailed above is meant to be illustrative only and not limiting. For example, this invention can be used in a system for any discharge lamp which employs metal vapor and a rare gas. Moreover, the present invention can be used in any fluorescent electroded compact lamp. Other embodiments of circuitry for providing stability in either an electrically isolated power supply system or an electrically non-isolated power supply system will be obvious to those skilled in the art.

IN THE CLAIMS

I claim:

1. A power system having an AC input voltage and DC output voltage comprising:

a controller coupled to a supply of said AC input voltage;

a primary winding coupled to said controller;

a secondary winding inductively coupled to said primary winding for providing said DC voltage;

an auxiliary winding inductively coupled to said primary winding;

a path coupled between said auxiliary winding and said controller for providing a voltage supply to said controller; and

a separate voltage feedback path coupled between said auxiliary winding and said controller for providing an accurate representation of said DC output voltage to said controller.

2. The power system of Claim 1 wherein said separate voltage feedback path comprises a diode, a resistance, and a capacitor.

3. The power system of Claim 2 wherein said system is used to power an electrodeless discharge lamp.

4. The power system of Claim 2 wherein said system is used to power any discharge lamp which employs a metal vapor and a rare gas.

5. The power system of Claim 2 wherein said system is used to power a fluorescent electroded compact lamp.

6. A power supply for an electrodeless discharge lamp comprising:

a controller coupled to an AC input voltage;

a primary winding coupled to said controller;

an auxiliary winding inductively coupled to said primary winding and coupled to said controller; and

means for allowing a power transfer from said primary winding to said auxiliary winding, said means coupled to said controller and said primary winding; and

means for generating an output DC voltage coupled to said controller,

wherein said auxiliary winding provides a voltage supply to said controller, and wherein said means for generating further provides an accurate representation of said output DC voltage to said controller.

7. A power supply for any discharge lamp which employs a metal vapor and a rare gas comprising:

a controller coupled to an AC input voltage;

a primary winding coupled to said controller;

an auxiliary winding inductively coupled to said primary winding and coupled to said controller; and

means for allowing a power transfer from said primary winding to said auxiliary winding, said means coupled to said controller and said primary winding; and

means for generating an output DC voltage coupled to said controller,

wherein said auxiliary winding provides a voltage supply to said controller, and wherein said means for generating further provides an accurate representation of said output DC voltage to said controller.

8. A power supply for a fluorescent electroded compact lamp comprising:

a controller coupled to an AC input voltage;

a primary winding coupled to said controller;

an auxiliary winding inductively coupled to said primary winding and coupled to said controller; and

means for allowing a power transfer from said primary winding to said auxiliary winding, said means coupled to said controller and said primary winding; and

means for generating an output DC voltage coupled to said controller,

wherein said auxiliary winding provides a voltage supply to said controller, and wherein said means for generating further provides an accurate representation of said output DC voltage to said controller.

AMENDED CLAIMS
[received by the International Bureau on 14 September 1993 (14.09.93); original claims 6-8 amended; new claims 9-32 added; remaining claims unchanged (4 pages)]

a primary winding coupled to said controller;

an auxiliary winding inductively coupled to said primary winding and coupled to said controller;

means for allowing a power transfer from said primary winding to said auxiliary winding, said means coupled to said controller and said primary winding;

a voltage feedback path coupled between said auxiliary winding and said controller; and

means for generating an output DC voltage coupled to said controller.

7. A power supply for any discharge lamp which employs a metal vapor and a rare gas comprising:

a controller coupled to an AC input voltage;

a primary winding coupled to said controller;

an auxiliary winding inductively coupled to said primary winding and coupled to said controller;

means for allowing a power transfer from said primary winding to said auxiliary winding, said means coupled to said controller and said primary winding;

a voltage feedback path coupled between said auxiliary winding and said controller; and

means for generating an output DC voltage coupled to said controller.

8. A power supply for a fluorescent electroded compact lamp comprising:

a controller coupled to an AC input voltage;

a primary winding coupled to said controller;

an auxiliary winding inductively coupled to said primary winding and coupled to said controller;

means for allowing a power transfer from said primary winding to said auxiliary winding, said means coupled to said controller and said primary winding;

a voltage feedback path coupled between said auxiliary winding and said controller; and

means for generating an output DC voltage coupled to said controller.

9. The power system of Claim 1 wherein said separate voltage feedback path comprises means for rectifying the induced voltage through said auxiliary winding.

10. The power system of Claim 9 wherein said means for rectifying includes a diode.

11. The power system of Claim 1 wherein said separate voltage feedback path comprises an AC filtering element.

12. The power system of Claim 11 wherein said AC filtering element includes a capacitor.

13. The power system of Claim 1 wherein said separate voltage feedback path comprises a resistance.

14. The power system of Claim 13 wherein said resistance includes a voltage divider network.

15. The power supply of Claim 6 wherein said voltage feedback path comprises means for rectifying the induced voltage through said auxiliary winding.

16. The power supply of Claim 15 wherein means for rectifying includes a diode.

17. The power system of Claim 6 wherein said voltage feedback path comprises an AC filtering element.

18. The power supply of Claim 17 wherein said AC filtering element includes a capacitor.

19. The power supply of Claim 6 wherein said voltage feedback path comprises a resistance.

20. The power supply of Claim 19 wherein said resistance includes a voltage divider network.

21. The power supply of Claim 7 wherein said voltage feedback path comprises means for rectifying the induced voltage through said auxiliary winding.

22. The power supply of Claim 21 wherein means for rectifying includes a diode.

23. The power supply of Claim 7 wherein said voltage feedback path comprises an AC filtering element.

24. The power supply of Claim 23 wherein said AC filtering element includes a capacitor.

25. The power supply of Claim 7 wherein said voltage feedback path comprises a resistance.

26. The power supply of Claim 25 wherein said resistance includes a voltage divider network.

27. The power supply of Claim 8 wherein said voltage feedback path comprises means for rectifying the induced voltage through said auxiliary winding.

28. The power supply of Claim 27 wherein means for rectifying includes a diode.

29. The power supply of Claim 8 wherein said voltage feedback path comprises an AC filtering element.

30. The power supply of Claim 29 wherein said AC filtering element includes a capacitor.

31. The power supply of Claim 8 wherein said voltage feedback path comprises a resistance.

32. The power supply of Claim 31 wherein said resistance includes a voltage divider network.

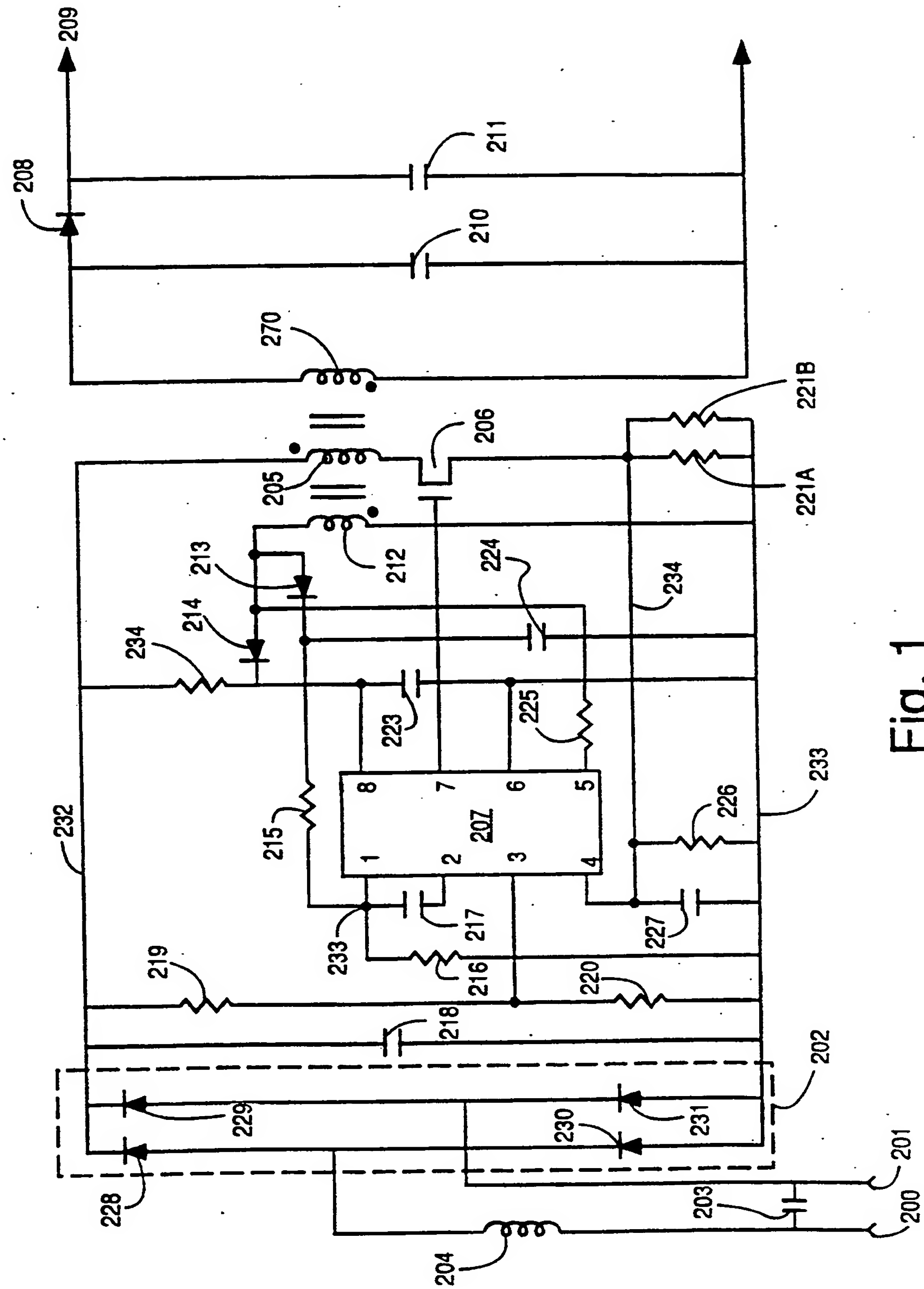

209
208
211
210
270
206
205
221B
221A
212
213
214
224
234
234
223
225
207
8
7
6
5
1
2
3
4
215
226
233
232
217
227
233
216
219
220
218
202
229
231
230
201
228
203
200
204

Fig. 1

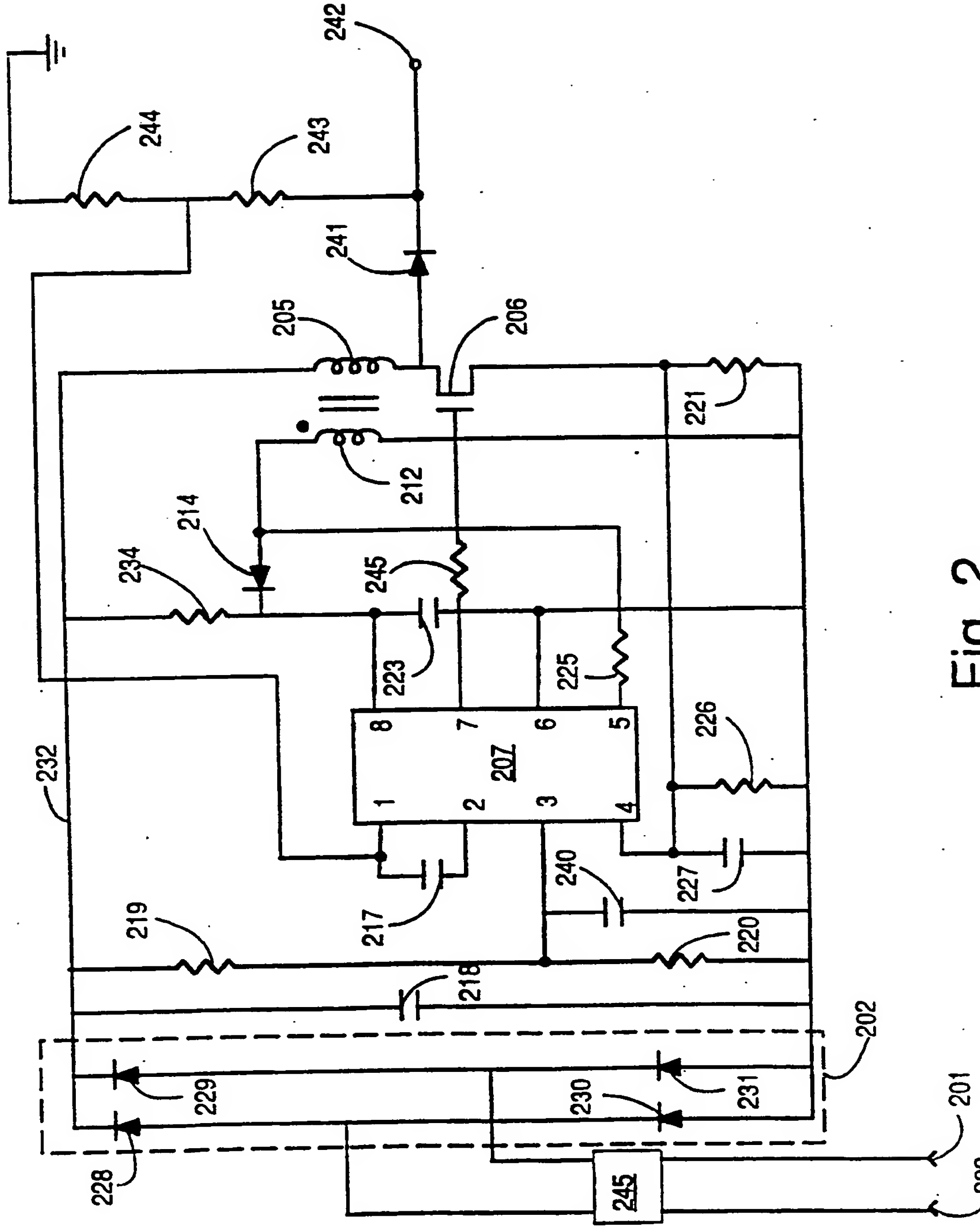

242
244
243
241
205
206
221
212
214
234
245
223
225
207
8
7
6
5
1
2
3
4
226
232
227
240
217
219
220
218
202
229
231
230
201
228
245
200

Fig. 2

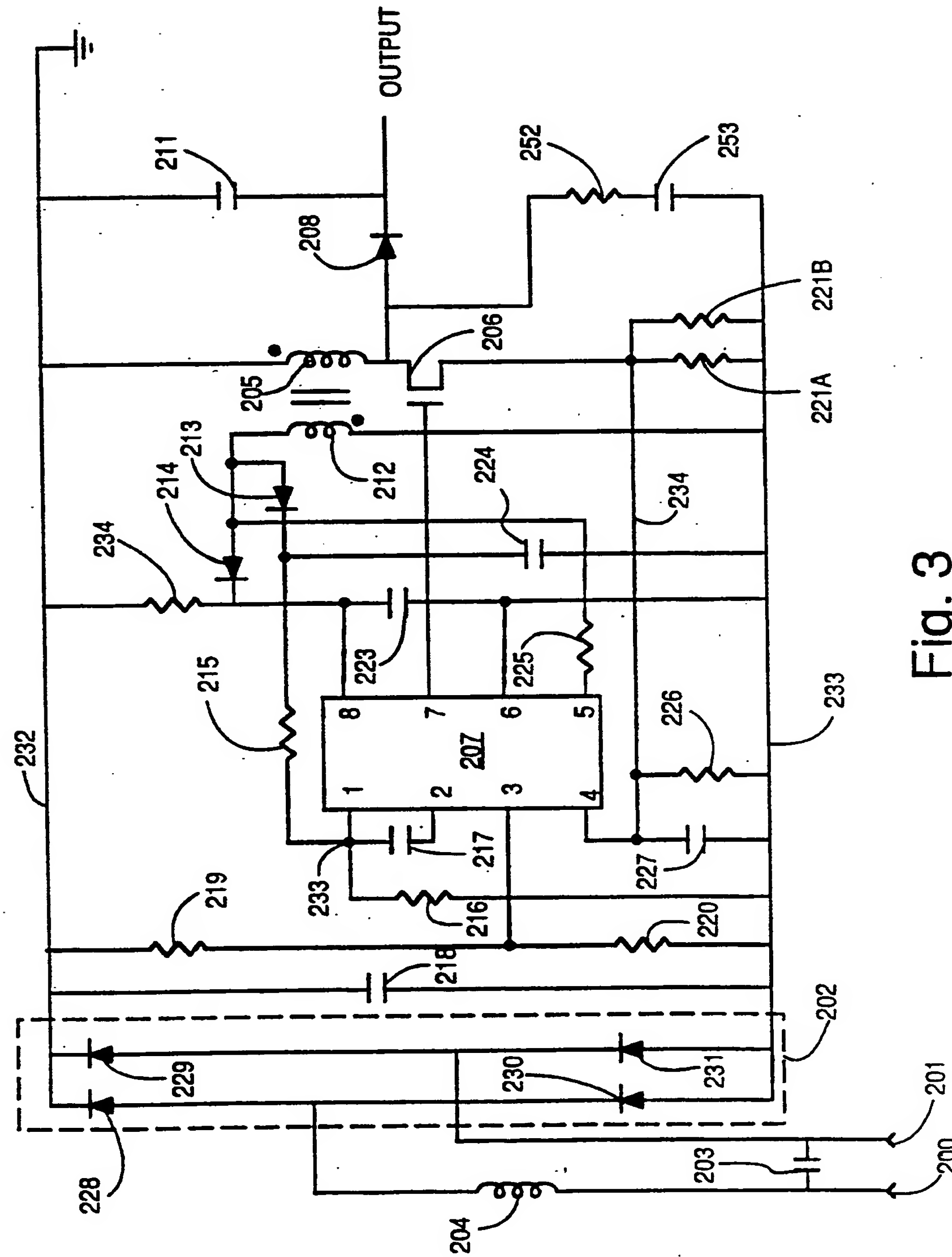

OUTPUT
211
208
252
253
206
205
212
213
214
224
221B
221A
234
234
215
223
225
207
8
7
6
5
1
2
3
4
226
233
232
217
233
227
219
216
220
218
202
229
230
231
228
203
201
200
204

Fig. 3